Physics Flash

October 2011

INSIDE

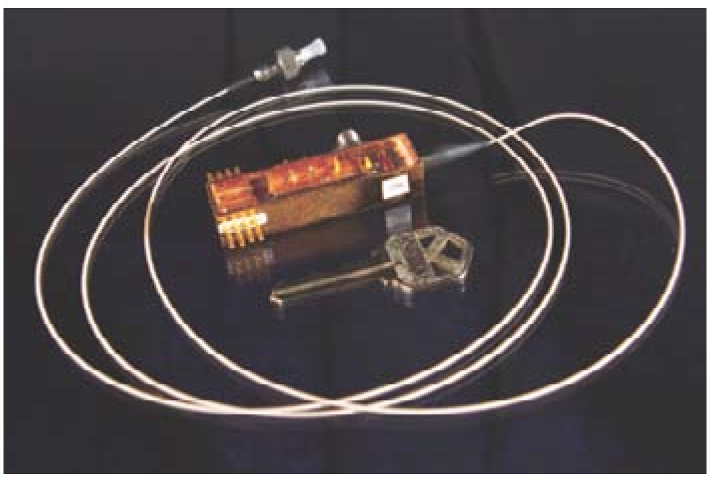


# Keeping secrets safe forever

## *QKarD brings quantum cryptography to handheld devices*

Mobile devices and smart phones may soon be equipped with an impenetrable line of defense known as QKarD, a patent-pending technology that loads quantum cryptography onto a smartcard or smart phone.

The culmination of 18 years of research at Los Alamos National Laboratory, QKarD uses a new type of symmetric key distribution, known as quantum cryptography or quantum key distribution (QKD), based on the quantum mechanical laws of physics.



*QKarD uses miniaturized quantum cryptography technology so it can work in a mobile device and no longer needs dedicated fiber optic lines to encrypt communications. The proof-of-principle device will be manufactured in a smaller package at the chip level for production.*

To encrypt and decrypt messages, cryptographic algorithms require the sender and receiver to both have the same secret keys–to determine how their cryptographic functions operate mathematically. Keys can be delivered to the users either symmetrically or asymmetrically.

Asymmetric key delivery is commonly used today but is based on difficult mathematical problems. Its security cannot be guaranteed, and it can be difficult for a small device to perform the mathematics. QKD distributes keys with much higher security and much lower computational requirements.

Current quantum key distribution systems are bulky, rack-mounted systems that require dedicated fiber optic lines to connect users, within limited distances, and second lines to carry all other optical signals needed for the protocol information and the secured data. QKarD minimizes this technology to fit into smaller devices, such as a smartphone, wireless credit card, or identification card, and can be used whether the device is plugged into a charging/docking station or is being carried around by the user.

Designed by Jane Nordholt, Richard Hughes, Raymond Newell, Charles Peterson (all of Applied Modern Physics, P-21); Kevin McCabe and Nicholas Dallmann (Space Instrumentation System, ISR-4); and Kush Tyagi (formerly of ISR-4), QKarD's miniature BB84 transmitter communicates with a designated central trusted authority to generate random cryptographic keys to encode and decode

*continued on page 2*

**QKarD . . .** information. The laws of quantum physics and information theory ensure that these keys can never be cracked, regardless of advancements in computer technology, according to the researchers.

To make a secure phone call on a smartphone, you would first authenticate yourself with a password and perhaps biometric readings taken by a fingerprint reader or standard camera for iris or face recognition on the QKarD. You would then dial the number of User B, a person with a QKarD. If User B is in your nonsecret lookup table, your QKarD can use its secret keys to set up a secure call. If User B's information isn't in your lookup table, your QKarD calls the trusted authority via a normal cellular call, and one of the QKarD keys is used to encrypt the key that the trusted authority wants you to apply to the phone call.

Available for licensing since August 2010 with an expected price of $200 to $500 per unit, QKarD is positioned to replace current security systems for banking, online transactions, access to secure facilities, border crossings, digital rights management controls, and electronic voting. It is foolproof and more affordable.

In an era when even U.S. presidents depend on their mobile devices, what stands out as "revolutionary" about QKarD, according to its developers, is unrivaled security coupled with portability.

*Contact: Jane (Beth) Nordholt*

## *JMR* cover features Los Alamos research


Los Alamos researchers recently got the cover article for the *Journal of Magnetic Resonance* with work using room-temperature atomic magnetometers that provide a magnetic resonance imaging system that is cost-effective, convenient, compact and portable.

Ultra-low field (ULF) MRI methods became feasible for anatomical imaging thanks to the method of switched prepolarization and the sensitive magnetic field detection of nuclear spins with low-Tc SQUIDs in a mu-metal shielded room, needed to compensate for extremely low levels of the NMR signal. ULF MRI has many potential advantages such as low cost, portability, convenience, enhanced contrast, open design, absence of susceptibility artifacts, and some others. However, the use of SQUIDs and a shielded room is a significant drawback. For example, a SQUID-based system is not cheap and has to be attended frequently, thus being less convenient compared to conventional MRI scanners based on superconducting magnets, which require minimal maintenance related to the liquid helium.

At Los Alamos, to make ULF MRI applications commercially viable, the researchers have worked on developing alternative non-cryogenic detection methods. In their preliminary experiments, they found that with a resistive flux transformer, an atomic magnetometer can be easily substituted for SQUIDs in ULF MRI. However, the resistance of the flux transformer, which was made of copper wire and operated at room temperature not to rely on the use of cryogens, introduces significant Johnson noise deteriorating the magnetic field sensitivity below that of low-*Tc* SQUIDs.

From the analysis, it follows that the sensitivity can be much improved by increasing NMR frequency. Actually, by changing the frequency from 3 kHz to 85 kHz (still keeping most of the advantages of the ULF regime) and by increasing the prepolarization field strength from 400 G to 1 kG, they were able to improve sensitivity by more than an order of magnitude. As a result, they obtained 9 MRI 5-mm slices with in-plane resolution of 2.5x2.5 mm2 in 5 minutes of acquisition (see figure, next page).

In addition to removal of cryogenic requirement, they were also able to achieve high sensitivity and good quality of MRI without a shielded room or any large-size structure, thus making our system cost-effective, convenient, compact, and portable. They used only one detection channel for obtaining ULF MRI – a coil resonated by a capacitor and an amplifier. However, a one-channel operation is not optimal in terms of sensitivity, field of view, and scan time. Using atomic magnetometers, it will be possible to implement a high-sensitivity multi-channel non-resonant MRI detection system. This would make their ULF MRI scanner on par in terms of image quality with other scanners used for anatomical imaging.

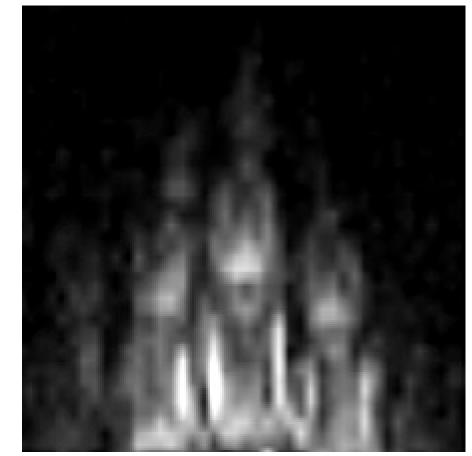
More importantly, the multi-channel system would allow them to move from small-size imaging such as that of a hand demonstrated the figure below to large-size imaging of head, spine, or even whole body by covering the imaging area with an array of flux transformers connected to atomic magnetometers, each operating independently due to the absence of resonating currents in the coils. The hand image is only the first step showing feasibility of the non-cryogenic ULF method of anatomical imaging. Work on the development of a ULF MRI non-cryogenic scanner for the human brain is in progress.

*continued on page 3*



**JMR . . .** Researchers include Igor Savukov, Todor Karaulanov, Petr Volegov, Andrei Matlashov, Michelle Espy, Algis Urbaitis, John Gomez, Shaun Newman (all P-21) and A. Castro(LANL). The work is is supported by NIH grant R01EB009355.

Reference: "Non-cryogenic anatomical imaging in ultra-low field regime: Hand MRI demonstration" *JMR*, **211**, Issue 2, 101-248 (2011)



*Hand MRI at 85 kHz.*

## Requirements for a spherical imploding plasma liner to reach high energy density and fusion-relevant conditions

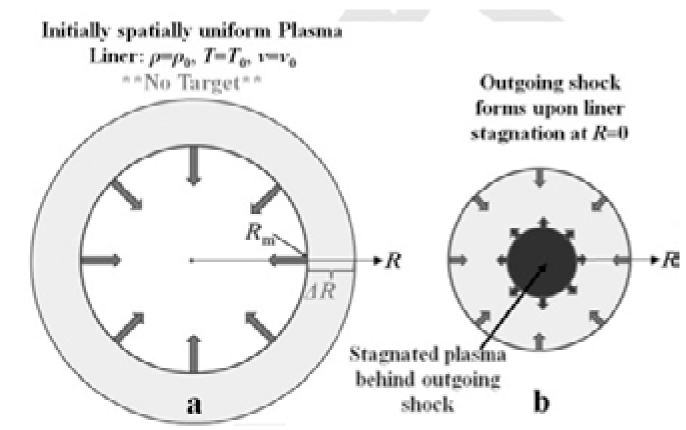
Imploding spherical plasma shells, or "liners," formed by an array of convergent high Mach number plasma jets, are potentially attractive for forming centimeter (cm) and microsecond (μs)-scale high energy density (HED) plasmas for scientific studies and as a standoff driver for magneto-inertial fusion (MIF).

In research accepted for publication in *Physics of Plasmas*, Physics Division researchers and collaborators report on one-dimensional radiation-hydrodynamic simulations performed to examine the scaling of stagnation pressure as a function of the initial conditions of imploding, spherically symmetric plasma liners. The work supports the objectives of the Plasma Liner Experiment (PLX) in Plasma Physics (P-24).

This work provides insight into the requirements for creating HED and fusion-relevant conditions in the laboratory via the implosion of a spherical plasma liner. The simulations, which ignore multi-dimensional effects but include radiation transport and thermal conduction, and use liner parameters to be achieved by PLX, suggest that plasmas with stagnation pressures near 1 Mbar can be sustained for 1 μs, or that pressures near 10 kBar can be sustained for 10 μs.

It is shown that radiation and thermal conduction must be included in simulations to avoid the formation of an unphysical, high temperature "plasma bubble" which artificially limits the convergence and peak pressure achieved by the imploding plasma liner. By examining a variety of liners with parameters outside of those accessible to PLX, scaling laws for higher energy liners have been obtained, which can be used to evaluate the imploding plasma liner approach for creating HED and MIF-relevant conditions. The simulation results show that the stagnation pressure (1) is maintained for a time approximately equal to the initial liner thickness divided by its initial velocity, (2) scales as the initial liner density to the ½ power and to the initial velocity to the 15/4th power, and (3) scales as the initial liner Mach number to the 3/2 power. This information will aid in guiding experimental campaigns on PLX and in the design of future imploding plasma liner experiments.

Computational results suggest that the experimental data will provide a unique and rich dataset for validating transport and equation of state models.




*Physical (cross-sectional) picture of a (left) spherical plasma liner imploding on vacuum, and (right) an outgoing shock propagating into the back of the incoming liner after the front of the liner reaches the origin, with high pressure plasma behind the shock.*

The work, by Thomas Awe, Colin Adams, Joshua Davis, David Hanna, and Scott Hsu (all P-24 or formerly P-24), and Jason T. Cassibry (University of Alabama, Huntsville), was supported by the DOE Office of Fusion Energy Sciences (LANL program manager Glen Wurden).

*Technical contact: Scott Hsu*

# Omega EP and Trident studies lead to new understanding of ion focusing and new tools for future applications

In the study of defects in inertial confinement fusion (ICF) capsules, which are used in a laser-driven system for creating fusion energy, Los Alamos experimental team members Kirk Flippo, Dustin Offermann, Jim Cobble (P-24), and Mark Schmitt (Plasma Theory and Applications, XCP-6) have completed a new round of experiments at the Omega Extended Performance (Omega EP) laser facilities in Rochester, New York. They tested laser-generated ion beams from a laser 10 times higher in energy than similar lasers, such as the Laboratory's own Trident laser system, which operates at around 100 joules.

The research team is developing the laser-driven ion beams for ICF studies, with a particular emphasis on carbon ions. To do this, they also had to pioneer new tools they need to study the focusing characteristics of these beams.

They have already demonstrated the consistent production of multi-MeV ion beams using a kilojoule of short-pulse laser energy with a conversion efficiency of several percent, and proton beams of nearly 70 MeV, the highest energies seen on the EP laser, and near the world record in energy.

The ion beams are produced when an energetic and ultra-intense laser interacts with a thin solid target at relativistic intensities. The interaction produces large currents (MA) of electrons coursing through the target. The currents produce extreme electric fields on the rear surface on the order of teravolts per meter (TV/m), which in turn accelerate the ions into an MeV beam of roughly $10^{14}$ – $10^{15}$ ions in a picoseconds (10-12 sec). When focused, this beam has the potential of delivering 10's of joules of energy into a spot on the order of 10's of microns, pushing the local energy density out of balance.

Using a combination of experiments on the Trident Laser Facility and Omega EP, the team also demonstrated the non-ballistic focusing nature of the ions from hemi-shelled targets. This is the topic of a recent invited talk and article given at the American Physical Society Division of Plasma Physics's annual meeting in Chicago last November [D. T. Offermann et al. *Phys. Plasmas* 2011].

Similar work on non-ballistic proton beam focusing, which the Los Alamos team performed in collaboration with the University

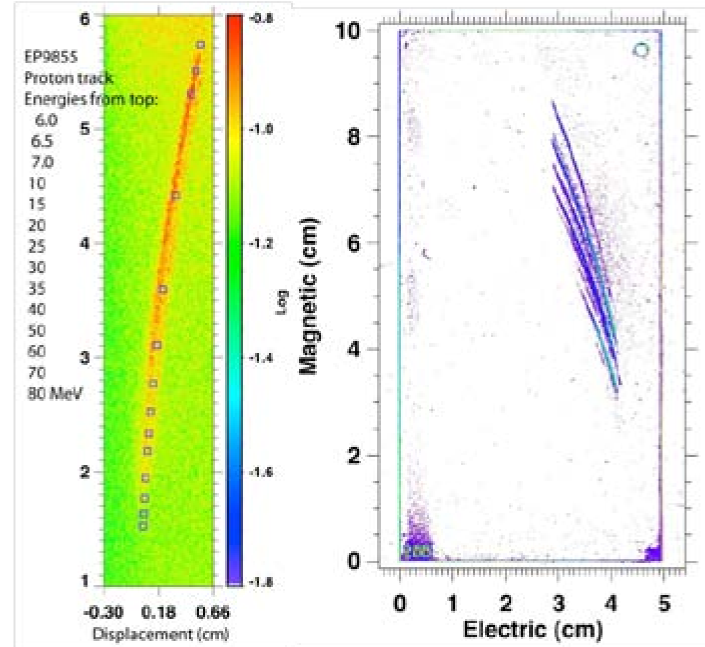



*Fig 1: Thomson Parabola (TPIE) data showing high energy protons up to nearly 70 MeV from the Omega EP using 1 ps and ~400 J of laser energy (left) and TPIE data showing carbon species up to 30 MeV in energy using 10 ps and 1000 J of laser energy.*

of California, San Diego and Livermore, is being prepared for publication.

This work has led to a new design for a focusing target, the "cusped-hemi," which is a modified hemi-shell target with multiple radii of curvature to optimize the ion focusing and conversion efficiency. These "cusped-hemis" are made from 10-micron thick diamond using chemical vapor deposition. The latest campaign at Omega EP in July tested these novel targets; the preliminary results indicate that they have out-performed their progenitors.

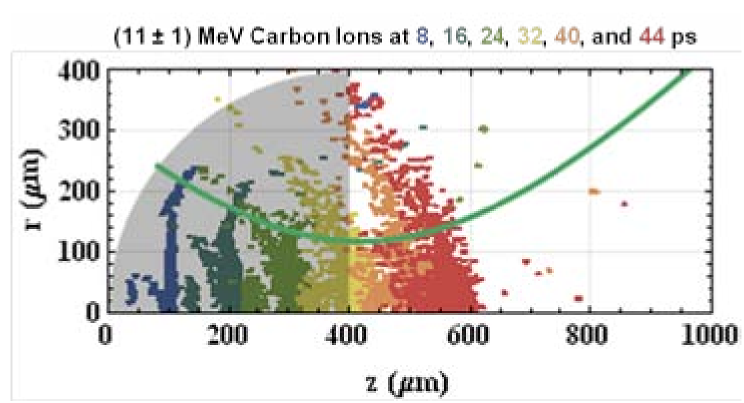



*Fig 2: Simulated spatial-temporal data from the Lsp code showing 11 MeV ions in a 1 MeV band for different time steps (colors) born on the hemi-shell inner surface (gray) accelerated to the right, and the ensemble trajectory as the green line overlay.*

In ICF, a strong shock wave (high-pressure pulse) implodes (collapses) a millimeter-size spherical capsule to about a thousandth

continued on page 5



**Studies . . .** of its original volume. Deuterium-tritium (DT) gas within the capsule gets so compressed and hot that its nuclei begin to fuse into helium nuclei, releasing large amounts of nuclear energy. That energy, in turn, provides the heat to sustain additional fusion reactions. But any small bumps or imperfections that develop during the implosion will rapidly grow and cause the capsule shell to mix with fuel, damping the heating process and perhaps even quenching the fusion burn, and causing the capsule not to ignite.

The ignition of ICF capsules is a major milestone for the National Ignition Campaign (NIC) at the National Ignition Facility (NIF), of which LANL is an integral part. This work was funded through Campaign 10 (Steve Batha).

*Technical contact: Kirk Flippo*

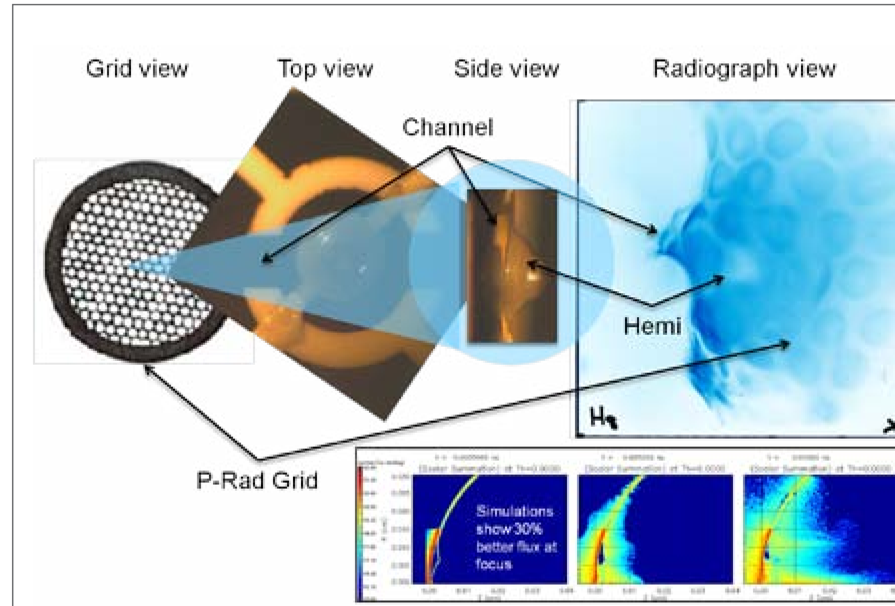



*Fig 3: Proton radiograph (p-Rad) of a cusped hemi (far right), starts with the radiography beam passing through a hexagonal grid (far left), and then the cusped hemi target assembly (center, top and side views) to create an image of the hemi target on a radiochromic film (RCF) stack with the grid superimposed (far right). The image in the RCF is formed from the cross-linking of a polymer dye in the active layer of the film caused by the energy deposited by the proton beam. The resulting image can then be deconvolved to measure the electric field strengths of the accelerating and preplasma fields formed by a second laser interacting with the hemi-apex, and used to refine the focusing design. Simulations show a 30 % increase in the flux of carbon ions at the focus of the cusped-hemi design compared to a traditional hemi-shell target (bottom right inset).*

# How Trees Die:

### *Signature imaging to unravel carbon starvation and dehydration dynamics in vegetation during drought*

Los Alamos researchers have observed, for the first time, that water content can be monitored non-invasively and unobtrusively in intact trees via ultra-low-field/nuclear magnetic resonance (ULF NMR). The researchers have seen evidence of both changes in water content for day vs. night in an aspen tree, as well as the overall decline in water content as the tree is dying. The work represents a first in application of the ULF NMR method to the study of plant function and mortality. Additional validation with traditionally accepted environmental methods is underway. If validated, the work appears to represent a first non-invasive look at how water movement changes inside an aspen tree over time and during the onset of mortality.

The work was accomplished using LDRD Science of Signatures reserve funding. The effort demonstrates that the combination of Los Alamos's unique abilities in ultra-low field magnetic resonance imaging, with climate-driven vegetation mortality research can provide insight into basic questions of plant function and mortality.

**Their ultimate aim is to provide basic insights into questions such as how plants die, especially during drought.**

Their ultimate aim is to provide basic insights into questions such as how plants die, especially during drought. While the question of plant mortality is easy to conceptualize, it is difficult to study because of the spatial and temporal variation of processes over the plant. Understanding these mechanisms of mortality, especially the tipping points, will provide critical input to forecasts of future climate because presently models cannot simulate vegetation change and related climate effects. The work here represents a first step towards fieldable, non-invasive monitoring to answer these fundamental questions.

Researchers include M. Espy (P-21), N. McDowell (Earth System Observations, EES-14), J. Resnick (P-21) I. Savukov (P-21), and S. Sevanto (EES-14).

continued on page 6

**Trees...**

Figure 1 shows the overall experimental set-up and decline of the tree due to a parasitic infection common to aspens in New Mexico. Figure 2 shows calibration data correlating water content and NMR signal. Figure 3 shows, for the first time, the day night water cycle of the aspen recorded by continuous ULF NMR. The spikes are associated with their instrumentation. The overall day/night cycle is apparent with a peak in late evening and a minimum in mid-day.

*Technical contact: Michelle Espy*

*Figure 1. Top row: Two photos of the tree in the ULF NMR system. The NMR system is located inside the silver magnetic shield. The photo at left was taken ~7 days before the photo at right, and significant decline in leaves is noted. Bottom row: Left shows close up of leaves infected with parasite. Right shows close up of NMR system around tree trunk.*

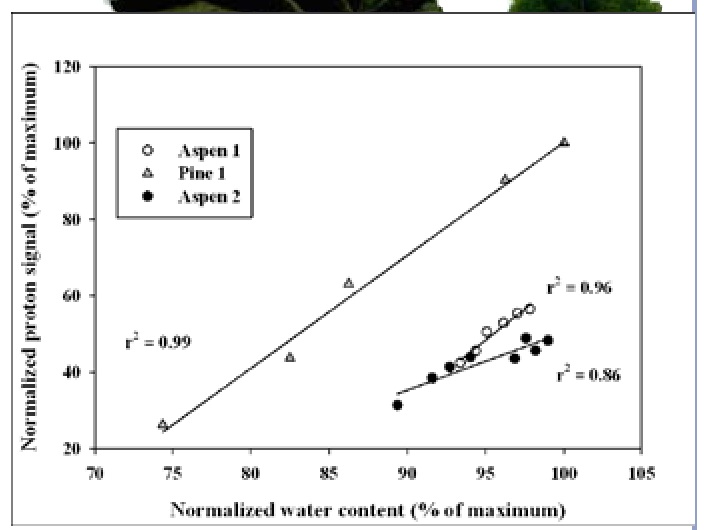



*Figure 2. Calibration data showing correlation between weight and ULF NMR signal in a dying branch.*

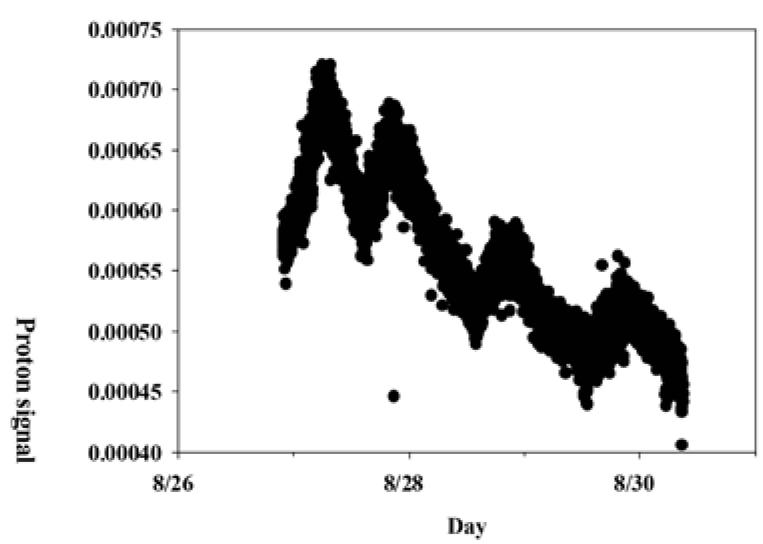



*Figure 3. ULF NMR signal from aspen tree over three days. A daily cycle associated with the NMR signal (water content) is present, as is a downward trend that appears to correlate with overall decline of the tree's health.*



# HeadsUP!

## Seasonal flu vaccine available through local pharmacies

*Present your LANS Blue Cross Blue Shield card*

The 2011 seasonal flu vaccine is available now from area pharmacies, clinics, and personal medical providers. LANS employees can receive the seasonal vaccine from many local providers and pharmacies without a co-pay by presenting their Blue Cross Blue Shield of New Mexico health plan card. Employees should call ahead to check hours and availability. Occupational Medicine will not be providing the flu vaccine onsite except for those LANL workers who receive the flu vaccine as part of their medical surveillance program.

In addition, the seasonal flu vaccine will be available free of charge at many community health fairs between now and the end of October. A list of locations in New Mexico contracted by Blue Cross Blue Shield of New Mexico to provide the seasonal flu vaccine at no out-of-pocket charge to individuals covered by the BCBS health plan is at http://int.lanl.gov/news/newsbulletin/pdf/vaccine_network_list_092810.pdf. Employees are encouraged to call pharmacies first to find out what times the flu vaccine will be offered.

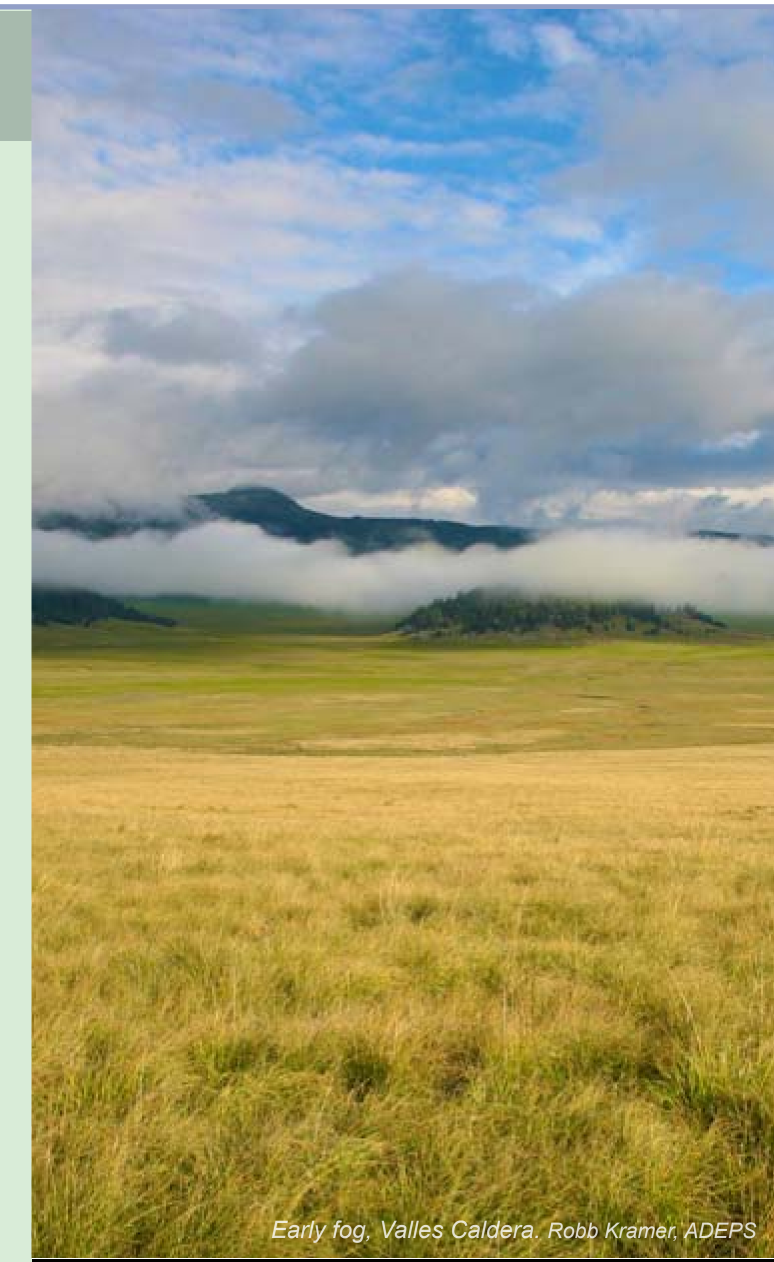
## Tag your bags

Don't let your unattended belongings be mistaken for a suspicious package and "destroyed." Visit the Tag Your Bag webpage at int.lanl.gov/safety/emergency/emergency_management/tag_your_bag.shtml for more information on the importance of placing identification tags on bags and other personal carriers.

To report unattended and suspicious bags or packages, contact the Protective Force immediately at 7-4437.

## Winter closure information

An all-employee memo about LANL's 2011 winter closure was issued by Associate Director for Business Services Mark Barth. Read the memo at int.lanl.gov/memos/2011/09/LANL-ALL2447.pdf for more information.



*Early fog, Valles Caldera. Robb Kramer, ADEPS*

## Celebrating service

Congratulations to the following Physics employees celebrating service anniversaries this month:

| | |
|---|---|
| Chris Morris, P-25 | 35 years |
| Paul Nedrow, P-23 | 10 years |
| Larry Schultz, P-21 | 10 years |

Physics Flash

is published by the Experimental Physical Sciences Directorate.
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LALP-11-014

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